

Conclusions & Recommendations

Workshop on **Research & Training Needs in the Field of Integrated Vector-borne Disease Control in Riceland Agroecosystems of Developing Countries**

9-14 March 1987

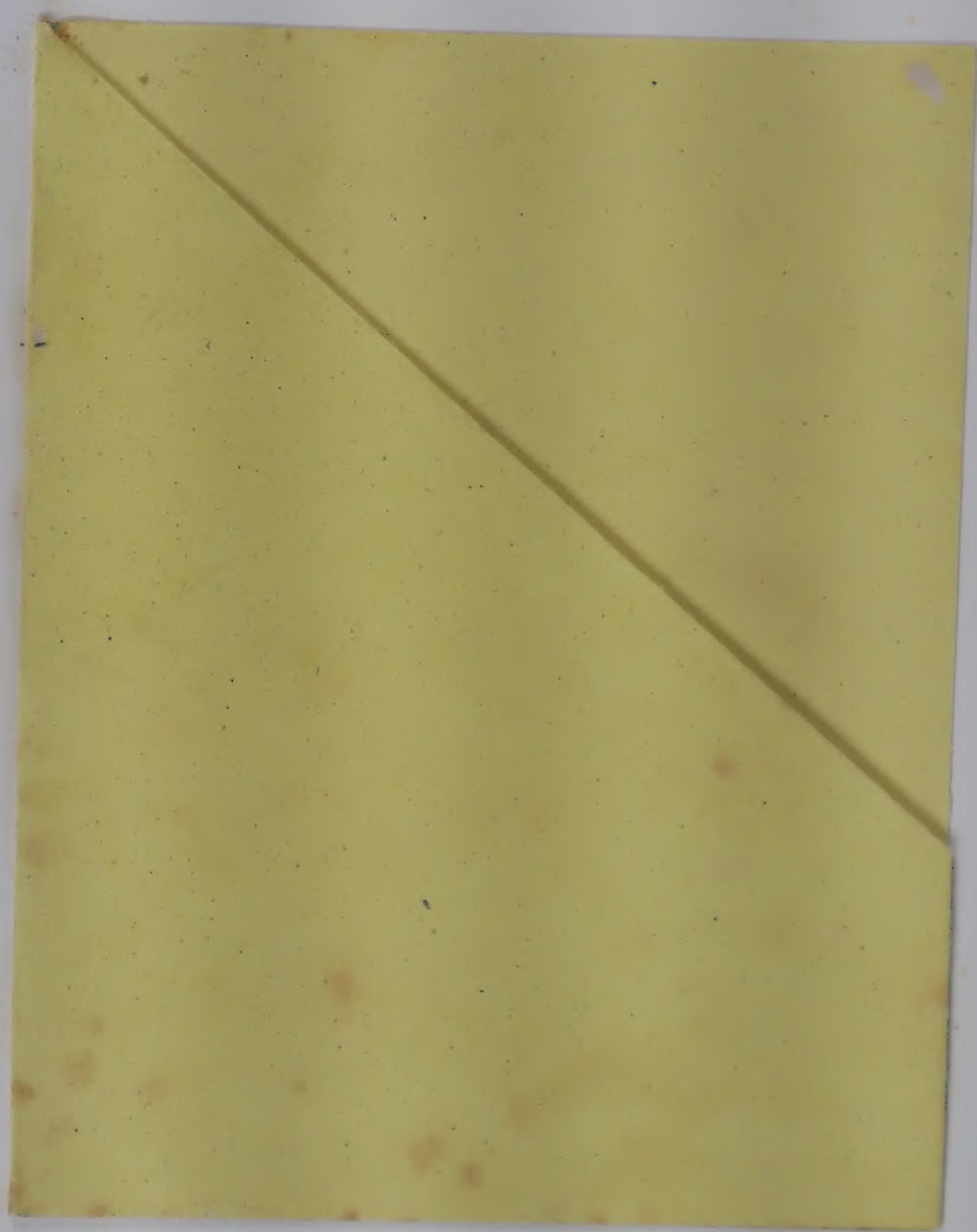
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Environmental Management for Vector Control

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Abbreviations used in this book:

ADB	Asian Development Bank
AfDB	African Development Bank
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
IADB	Inter American Development Bank
ICID	International Commission on Irrigation and Drainage
IIMI	International Irrigation Management Institute
IITA	International Institute for Tropical Agriculture
IRRI	International Rice Research Institute
IUCN	International Union for the Conservation of Nature and Natural Resources
NGO	Nongovernmental organization
PEEM	WHO/FAO/UNEP Panel of Experts on Environmental Management
UNEP	United National Environmental Programme
WADB	West African Development Bank
WARDA	West Africa Rice Development Association

Introduction

Vector-borne diseases adversely affect the health and quality of life of millions of people in the tropics and subtropics. These diseases may be parasitic, bacterial, or viral. They are distinguished by their mode of transmission.

In the majority of vector-borne diseases, the infective agent is carried from one individual to another by an arthropod species of the insect class. They include malaria, the filariases, the trypanosomiasis, the leishmaniasis and a number of virus infections (arthropod-borne or arboviruses), such as Japanese encephalitis and other encephalitides, yellow fever, and dengue.

In many cases the pathogenic organism goes through some of its developmental stages inside the vector, but in all cases it multiplies, sexually or asexually, inside the vector. Schistosomiasis (bilharzia) follows a similar pattern. The difference is that the aquatic or amphibious snail species in the transmission cycle act as intermediate hosts for the asexual stages of the schistosome parasites. They do not carry the disease from one human to another. The infective stages of this parasite, the cercariae, swim about freely in contaminated water after they have been shed by the snails.

Malaria, schistosomiasis, and Japanese encephalitis are important vector-borne diseases associated with rice production in developing countries. Their causal agents are directly or indirectly associated with aquatic environments through the ecological requirements of certain stages in the life cycles of the pathogens or their vectors. (Vectors is used in a broad sense and includes primary and intermediate vertebrate and invertebrate hosts and animal reservoirs of human and animal diseases.)

Similarly, rice production is dependent on water. Many common rice varieties need continuous flooding for their development and optimum yield. In many instances the rice agroecosystem perfectly fits the ecological requirements of pathogens or their vectors.

The collaborative research of agronomists, vector ecologists, vector-control specialists, epidemiologists, civil and agricultural engineers, and, sometimes of sociologists and economists, will be required to solve the inherent problems and clarify the relevant issues.

Appropriate training programs are the key to the successful application of effective and acceptable solutions to the control of vector-borne disease transmission associated with rice production in the tropics and subtropics.

It was against this background that the Workshop on Research and Training Needs in the Field of Integrated Vector-borne Disease Control in Riceland Agroecosystems of Developing Countries was organized. The International Rice Research Institute; World Health Organization, Food and Agriculture Organiza-

tion of the United Nations, and United Nations Environment Programme, through their Panel of Experts on Environmental Management for Vector Control (PEEM); and the United States Department of Agriculture, through its Riceland Mosquito Management Program S122, sponsored the workshop.

The Workshop's objectives were to:

1. review vector-borne disease problems and their control as they relate to rice production in developing countries,
2. share research and experience, and gain insight into the nature, objectives, and progress of relevant research and training supported by the sponsoring agencies,
3. propose solutions to vector-borne disease problems associated with rice production in developing countries and anticipated problems as irrigation expands to meet the demands of rice production,
4. identify appropriate research and training to solve the problems,
5. recommend problem-solving approaches by national and international institutions, with special reference to collaboration between IRRI and PEEM, and
6. identify mechanisms to facilitate research and training.

The Workshop was held 9-14 March 1987 at the International Rice Research Institute (IRRI), at Los Baños, Philippines. The proceedings containing the working papers presented and a full account of the discussions are scheduled for publication in early 1988.

This summary serves to rapidly bring the conclusions and recommendations of the Workshop to the scientific community, professionals in national and international institutes, and donor agencies. It is hoped that this will lead to an equally rapid response, and that the short-term research and training recommended can be implemented soon.

Although substantial knowledge exists in each of the relevant specialties, Workshop participants noted that agricultural and medical specialization had created a communication gap with the result that measures were promoted or adopted for one purpose without due consideration of the other. The development of insecticide resistance by vectors exposed to agricultural pesticides was noted because it may negate epidemic control efforts. For example, cotton spraying along the American Pacific Coast has led to multiple resistance in the local malaria vector species *Anopheles albimanus*.

There is a need first for historical literature reviews to provide a basis for developing more effective vector-borne disease control strategies. Continued pressure for more rice production implies more intensive cropping in established rice-growing regions such as South and Southeast Asia and expansion into Africa and Central America. Some research would be directed toward the control of existing health problems and some toward prevention.

The Workshop considered strategies in basic and intervention research, especially in relation to environmental management for vector control to meet the physical, climatic, hydrological and sociological characteristics of different regions. The emphasis was on economical, agronomically compatible, and socially acceptable approaches that confer dual production-disease control benefits.

The training requirements are unique: disease problems must be identified and investigated by health professionals including biologists, epidemiologists, entomologists, and parasitologists. Solutions will require extensive research on the epidemiology and ecology of the diseases and on the agricultural practices related to them. That will require collaboration between health scientists, agronomists, and engineers. Ultimately, farmers and extension workers must apply the solutions in the field.

It is unlikely that most health groups will have ready access to all agricultural workers. Thus the main objective must be to train the trainers, those persons who will train agronomists, irrigation engineers, agricultural extension specialists, and others who deal with the agricultural community at the grass-roots level. These agricultural trainers will be far more aware than most health personnel of how changes in water management practices can be explained to farmers and irrigation technicians. They will also be more aware of the constraints and the reasons for changes in rice cultivation to suppress vector production and the subsequent transmission of disease.

Research needs recommendations

1. *Assess ricefield water-manipulation strategies to meet the twin goals of vector control and high rice yields; assess socioeconomic implications of adopting the most promising methods.*

The assessment should take a collaborative, interdisciplinary approach involving agronomists, vector ecologists, epidemiologists, agricultural engineers, and agricultural economists. Studies should encompass intermittent irrigation and other irrigation practices, water control infrastructures, and field leveling.

2. *Assign a WHO assistant professional officer in the field of medical entomology to work with IRRI agricultural scientists to assess the relation between crop production practices and vector bionomics.*

The APO's work program would be based on the short-term research priorities identified by this Workshop. This collaborative effort, consistent with recommendation 1, should include establishing a computerized database on vector-borne diseases in relation to rice production systems. This will give researchers more rapid access to such literature than is now possible.

3. *Establish the relations between agricultural management strategies and public health problems.*

Strategies that provide dual benefits as well as those that result in conflict need to be defined.

4. *Determine the relation between chemical treatments of ricefields and changes in the flora and fauna and the subsequent effect on pest and vector species.*

This work should be done collaboratively by agricultural and public health scientists.

5. *Determine the reasons that environmental management measures effective against vector-borne diseases have not been applied to water resource management.*

Research should address water impoundments, irrigation networks, and other catchment areas and involve engineers, sociologists, economists, epidemiologists, and vector ecologists.

6. *Collaborate with national agencies on studies of the advisability of introducing natural agents into agroecosystems.*

Fish and botanicals such as *Azolla* and Neem have the potential for controlling vectors and increasing farm productivity.

7. *Research rice varieties that can be managed to minimize vector breeding.*
8. *Continue research on vector-borne disease intervention strategies for settlements and landscapes.*
 - a. Study the influence of elevation of settlements and their distance from ricelands on protecting residents and temporary workers from malaria, Japanese encephalitis, and schistosomiasis. Factors to consider include water supply, sanitation, domestic animals, wind direction and other climatic conditions, behavior of vector species, and vegetative barriers to mosquito movement. Strategies to consider include placing domestic animals (with the exception of some reservoir animals such as pigs) between the ricefields and the settlement to divert vectors, treating bait animals with external or systemic insecticides, or placing mechanical traps in the vicinity of bait animals.
 - b. Establish structural specifications for housing to protect occupants from vectors. Among these are window and door screens, curtains, insect-tight roofs and walls, and insecticide-treated or untreated mosquito nets.
 - c. Determine the factors that have promoted or hindered the acceptance of known remedial practices to reduce disease transmission.
 - d. Assess the role of health education in promoting settlement-related intervention.
9. *Evaluate the efficacy of personal protection strategies in reducing disease transmission in the community and on the farm.*
10. *Conduct sociological studies to find more effective means of motivating the community to integrate vector-borne disease control into the primary health care system of riceland agroecosystems.*
11. *Continue to embrace recommendation 4 of the Fourth report of the WHO expert committee on vector biology and control. 1980. Environmental management for vector control.*

“Governments, if necessary with the collaboration of international organizations, should review the legislation available for regulating the development and use of natural resources in light of public health and environmental implications, introducing any complementary legal support that might be required.”
12. *Mobilize agricultural and health sciences researchers in the national programs of several disease-endemic countries to collaborate in the investigation of integrated vector-borne disease control in riceland agroecosystems.*

Such a research network would expand realization of the importance of interdisciplinary research and enable projects on several vector-borne diseases to be conducted in a number of countries.
13. *Make policy makers and administrators aware of the principles and objectives of these research recommendations.*

Research needs working group conclusions

BASIC RESEARCH NEEDS

Relative importance to disease of specific components of riceland ecosystems

Riceland ecosystems comprise several physical components, the ricefield proper, seepage areas, and irrigation networks, often in close association with wild and domestic animals and human habitation. The working group recognized the fundamental importance of the spatial and temporal quantification of vectors, intermediate hosts, vertebrate reservoirs of infection, and the human population at risk in relation to the design and implementation of cost-effective control strategies. The relative importance of each should also be considered in relation to different agronomic practices.

Successional changes in the biota

Extensive lists of vectors breeding in ricefields already exist. For some regions and some vectors, definitive studies of life table analysis, survivorship, time of maximum larval density, developmental time in relation to water temperature, and spatial distribution have already been published. For example, it is known that different mosquito species reach maximum larval densities at different stages of rice growth. The relative importance of such phenomena in relation to disease transmission and control needs to be established. Establishment of an inventory, over crop duration, of medically and agriculturally important insects is a high-priority, short-term goal, which may define overlaps and indicate mutual control benefits. Such an inventory, which should include potential biological control agents, will lead to the definition of areas for future research.

Assessment of vector breeding sites

Vector breeding sites can be assessed by established sampling methods although local techniques vary widely. Vector population densities vary markedly, but extensive rather than intensive sampling approaches yield more valuable data. Sampling methods should be directed at numbers/unit area to establish absolute population estimates.

INTERVENTION RESEARCH NEEDS

Vector populations in ricefields

Water regime manipulations. The effectiveness of alternative methods of manipulating on-field water regimes to eliminate or minimize breeding sites and reduce vector populations needs to be determined, and their impact on rice yields assessed for various soil types in different rice-production systems. They are essential for

devising water management methods that effectively control vector-borne diseases without reducing rice yield. Such evaluations should deal with intermittent irrigation as well as other irrigation practices.

Rice varieties that will permit the use of intermittent irrigation or periodic drainage should be developed. The role of water control infrastructure and management, including ricefield leveling, needs to be determined for the irrigation system as a whole and for the farm level. The socioeconomic implications of adopting the most promising methods also require assessment.

Alternative cropping. The efficacy of alternative upland nonrice crops, instead of double-cropped rice, to reduce vector breeding in endemic, rice monocrop areas needs to be determined. The economic impact of such crop rotations on individual farmers and the community should be studied. Research design should consider past experiences as in the Tjihea Plain, Java, Indonesia, during the 1920s.

Chemical and biological additives. Insecticides, herbicides, fungicides, and fertilizers will remain important in rice production. However, their impact on the rice ecosystem must be monitored to ensure that the main selection criterion is environmental safety rather than cost. Research on new and existing chemical control agents to determine efficacy, impact on nontarget organisms, and compatibility with the environment is necessary. Improved pesticide dispersal is needed to assure appropriate application levels without overdosing. Also, the timing of agrochemical applications must be studied to optimize both vector and agricultural pest control and minimize their harm to beneficial organisms.

Chemicals for controlling agricultural pests and vectors should be selected, and their application (including domestic residual vector-control application) timed, to minimize the potential of vectors to develop insecticide resistance.

Predators tend to move from canals and impoundments into ricefields. Therefore the value of propagating and maintaining larvivorous fish in ricefields should be investigated. The interaction of different fish species with each other, e.g., impact of *Gambusia* on the eggs of other fish, and with other beneficial organisms should be studied. Furthermore, the direct effect of fish on rice yield and on income per unit area should be assessed as well as methods to increase fish yield.

Pathogens, parasites, and predators that offer the potential for vector control should be carefully considered in the development of integrated control strategies. In general, the group endorsed the policy of using local products where possible.

IRRI research on the role of Neem in pest control and fertilizing suggests that its effect on repelling ovipositing gravid adults and on larval mortality should be studied. The usefulness of Neem cake to prolong fertilizer life should be explored in relation to larval control. The bonuses Neem provides are an incentive to its social acceptance.

Vector populations outside the ricefield

Important off-field habitats that present problems in regard to malaria, schistosomiasis, and Japanese encephalitis include:

1. impoundments in which stagnant water is held intentionally either in fish ponds, reservoirs, or night storage or unintentionally in borrow pits and depressed areas,

2. irrigation networks consisting of primary and secondary canals, hydraulic structures, and water control devices,
3. seepage water accumulations on lands below primary and secondary canals,
4. waste water accumulation in low lying areas as a result of disposal or seepage from the ricefields, and
5. drainage water retained in low points of canals or natural channels.

Remedial or intervention measures applicable to vector-borne disease control in these off-field habitats may be classified into one of three categories:

1. proven measures that could be applied without further research,
2. measures that work only under specific conditions and may be applied cautiously or on a pilot scale, and
3. measures that need further in-depth study in a specific situation before pilot-scale application can be considered.

In category 3, selected studies should determine the measure's effectiveness in reducing disease transmission, its technical feasibility, its economy, its environmental impact, and its social acceptance. For example, there is a need for benefit-cost analysis of lining major irrigation channels with concrete, and studies on increasing flow rates in canals to minimize mosquito and snail populations.

Reducing man-vector-pathogen contact

Settlement-related measures. The epidemiologies of malaria, schistosomiasis, and Japanese encephalitis differ greatly between communities even within the same rice-growing area. However, there are many vector-borne disease control measures that can reduce human infections regardless of these differences. They include siting houses away from breeding places; draining or eliminating breeding places adjacent to human housing; tight construction of walls, roofs, etc.; window screens and bed nets; siting animal shelters away from houses, vector-breeding sites, and disease reservoirs such as pigs; and providing adequate domestic water and sanitation. Failure to implement these measures may be due to the lack of adequate information, high cost, or institutional constraints. The reasons that many settlement-related vector-borne disease control measures are not being applied should be studied and appropriate steps taken to implement them.

Community action measures. There are many methods to control vector-borne disease in communities in riceland agroecosystems. These methods include animal-baited mechanical trapping, and zooprophylaxis for adult mosquitoes, reducing or eliminating vector breeding and pathogen contact sites; improved housing; pesticides; and community health education programs. In the case of zooprophylaxis, several examples of the use of animals to divert mosquitoes from humans are known. Recent analysis of the powerful nature of zooprophylaxis suggests that it should be investigated further. Zooprophylaxis could further reduce disease transmission if the diversionary animals were treated with insecticides. Citrus, lemon grass, Neem, or other botanicals with suspected repellent qualities could be incorporated into buffer zones around houses or villages. These crops would improve health and life style. Certain methods are unproven, but others require merely the organized efforts of the community for them to be effective. Efficacy research is needed on unproven tactics; socioeconomic studies and educational

programs are necessary to the effective application of proven methods.

Personal protection measures. Personal protection strategies that combine the use of pyrethroid-impregnated clothing and bed nets with topically applied repellents provide low-cost, virtually complete protection from mosquito bites. Although the acceptance and logistics of repellents may not be adequate, the protection impregnated clothing, bed nets, and household curtains afford field workers and riceland community residents against mosquitoes should be studied. Similarly, personal protection against schistosomes, such as avoiding exposure to contaminated water and wearing boots whenever possible, should be promoted and other approaches should be identified and evaluated. Studies should include assessment of the potential for acceptance of these individual protection methods. Also, toxic and allergic reaction to pesticide exposure of the community over time should be monitored.

OTHER RESEARCH CONSIDERATIONS

Innovative survey methods

Surveillance systems may be available but not necessarily readily applicable. The first priority should be assigned to vector surveillance and the second to disease surveillance. Recently developed immunological techniques are powerful surveillance tools. For example, enzyme linked immunosorbent assay (ELISA) is used for sporozoite identification of malaria and for epidemiological surveys of Japanese encephalitis and schistosomiasis. Existing techniques, however, should not be neglected. Short-term investigation of agricultural surveillance methods may uncover useful overlaps. For example, identification of potential vector breeding sites by remote sensing could be applied to both agricultural pest and vector-borne disease control in the future.

System analysis and modelling

Agencies planning vector-control strategies in rice should consider a systems approach. Decision-making is holistic but follows step-by-step procedure with the output of one step becoming input for the next. A strong monitoring, documentation, and evaluation program is essential to the systems approach, permitting experience to be relevant to similar projects. The systems approach has an inherent ability and flexibility, which can account for site-specific factors. Successful application of the approach and the corresponding integrated vector-control strategies, however, requires research-generated information such as the physical components of vector habitat, vector-borne disease epidemiology, and response to specific control strategies. Models for disease prediction are the logical outcome of improved surveillance. Field data need to be integrated into existing mathematical models. Several models have been developed for arboviruses such as Murray Valley encephalitis, St. Louis encephalitis, and dengue. Simulation is an economical tool for examining the impact of multiple variables on disease transmission and further development is required.

Training needs recommendations

1. *Encourage information exchange between health professionals concerned with vector-borne diseases and professionals in rice research and rice-production training.*

Rice workers should understand the relation between rice cultivation and irrigation and the vector-borne diseases that often follow. Health professionals need a better understanding of the engineering and water-management practices associated with rice farming and the constraints to altering these practices, particularly if they reduce rice yields.

2. *Include instruction in agriculture and water management, particularly as they relate to riceland ecosystems, in postgraduate courses in tropical health, medical entomology, and vector control. Include instruction on vector-borne diseases in postgraduate courses in agriculture and engineering.*

In this way, public health professionals will become familiar with the problems and needs of rice farming. And agriculture and engineering students will learn 1) the epidemiology of vector-borne diseases, 2) the biology of riceland-breeding vectors, and 3) potential vector-control methods, particularly as they relate to changes in irrigation patterns. Guidelines for incorporating a health component into engineering curricula are available at WHO.

3. *Conduct information seminars for health and agricultural specialists to ensure they are informed of new developments in vector control and problems that may arise in the field.*

IRRI and PEEM could organize these seminars with adequate support. PEEM should encourage ministries of health to undertake seminars through their primary health-care networks.

4. *Inventory riceland-related vector-borne diseases by country and region.*

WHO should initiate the inventory, which should incorporate an estimate of training facilities required by country in relation to the magnitude of vector-borne disease problems, the training facilities available, and training personnel at national and regional levels. The inventory should consider training needs for public health and agricultural workers and include a list of agencies that might provide funding, trainers, supplies, and instructional materials.

5. *Inform development and national planning agencies of riceland vector-control measures as they are elaborated so they can be incorporated into project designs at an early stage.*

Riceland vector-control measures certainly will include environmental and water management that should be included in project designs for the development of ricelands. WHO, FAO, and UNEP should share this responsibility, with PEEM serving as one information source.

6. *Prepare and distribute to extension trainers instructional materials on chemical and biological vector-control measures and on water and environmental management as soon as they are shown to be effective and economical in riceland ecosystems.*

PEEM and IRRI could disseminate training documents on chemical and biological vector control measures through their country contacts and collaborating agencies. Training material on water management and environmental control, however, should be distributed by IRRI. National water management and rice extension workers should have adequate training in the importance of vector-borne diseases associated with ricefields to assist them in training farmers and irrigation technicians.

7. *Train public health and agricultural workers on snail-borne diseases other than schistosomiasis.*

Snail-borne diseases other than schistosomiasis represent an increasingly important problem in several countries where schistosomiasis is either absent or is not a public health issue.

8. *Establish a computerized database on vector-borne diseases in relation to rice-production systems.*

This proposal, formulated under recommendation 2 of Research Needs Recommendations, applies equally to training needs.

9. *Review literature on the effects of agricultural and public health pesticides used in ricefields on nontarget predators of aquatic states of mosquitoes.*

UNEP, International Register of Potentially Toxic Chemicals, IUCN, and national agencies such as the U.S. Environmental Protection Agency may have this material on hand and should be asked to assist.

10. *Enlist greater involvement by national and international nongovernmental organizations in vector-borne disease training and education.*

More effort is needed to circulate information on vector-borne diseases and their control to NGOs. PEEM organizations might initiate this information and action program through their associated NGOs. The ultimate target of training programs is the farmer and the community in which he lives. All relevant techniques, including mass media, should be used to direct training to the farmer.

Training needs working group conclusions

SUBJECT MATTER

Any training course at whatever level should have as its first objective developing an awareness of the relation between rice production, the ecology of disease vectors, and the transmission of vector-borne diseases. Students should also be given, at a level concomittant with their training, the most important aspects of the epidemiology of those diseases with which they are most likely to come into professional contact. Finally, they should gain an understanding of the life cycles of the most important vectors of disease and, more specifically, how rice cultivation favors a particular vector. These subjects should be organized in modules, each one addressing a particular disease, rather than presenting the epidemiology of all diseases followed by details on their life cycles, ecology, and control.

The nature and scope of the subject matter in various training programs must, of course, depend on the background of the students, the length and content of the course, and whether it is part of the general curriculum for engineers or agronomists or is a special familiarization course. Whenever regular training courses are launched in a country, local training needs will have to be carefully assessed. Training may include short-term and long-term study as well as intensive workshops and specialized seminars.

If the training is given in a disease endemic country, training should include local case studies and, where possible, field visits to large- and small-scale water resource development projects. In any event the three most important diseases associated with rice production, malaria, Japanese encephalitis, and schistosomiasis should receive priority. If one or more do not exist in a given country, then the importance of mosquitoes as pests of man might be emphasized. In Asia, rice production and fish culture provide an ecological basis for transmission of other important snail-borne trematode infections such as clonorchiasis and opisthorchiasis.

The course should train the student not only in the general epidemiology of diseases and the ecology of their vectors, but in possible control methods. Emphasis should be given to environmental management measures that can be included at the planning, design, and construction phases of irrigation systems, as well as to the operation and maintenance. Control methods should consider water management, crop selection and rotation, the introduction of livestock, and other agricultural practices.

Particular attention should be given to practices to prevent or reduce vector breeding without reducing rice yield. The effects of natural or chemical fertilizers, and agricultural pesticides, including herbicides and fungicides, on disease vector populations or nontarget organisms should be included. Local manufacture of

indigenous botanical pesticides should be encouraged as substitutes for imported pesticides.

Organizers of training centers do not need to be concerned about the lack of trained personnel. Specialized health training centers such as those in ministries of health or schools of medicine or public health can assist. The extent of their participation must be determined with the school of engineering or agronomy that is introducing the subject. Such schools should be encouraged to make environmental management for vector control a part of the regular curriculum and not a one-time presentation.

Students and professors should evaluate such courses to ensure that they meet the needs and interests of both.

There is a general lack of trained professional entomologists and parasitologists. More training is needed in medical entomology and vector control, particularly in the field of aquatic biology, which is especially important in the study of vectors and nontarget organisms in ricefields. The working group called frequent attention to the lack of career opportunities in these areas and the need for correcting this situation.

In large rice production regions, entomologists, parasitologists, and agronomists should be equally familiar with diseases whose vectors breed in rice ecosystems and those associated with rice-growing communities.

Entomologists/parasitologists should receive sufficient information on basic engineering and agronomic principles relevant to environmental management for vector control. Such training would ensure communication between engineers, agronomists, and entomologists/parasitologists whenever they are jointly involved in rural development in rice-production areas.

APPROACHES

To rapidly provide accessible training facilities for the many countries faced with vector-borne disease problems in riceland ecosystems, the basic need is for modular training courses appropriate to regional and national needs.

Successful introduction of courses depends on the collaboration of institutions with established regional and national responsibilities. A coordination center to set standards for staff and training material, ensure efficiency, and monitor training effectiveness is required.

We do not recommend new agencies to provide training staff; existing facilities should be used to the extent possible. The coordinating center could draw on these facilities and have its own advisory panel and secretariat.

The regional approach would ensure that national institutions receive training materials and course modules best suited to their needs. It would also provide a better base for identifying extension training requirements and for translating and publishing middle- and lower-level training material along the lines followed by IRRI. Production, however, may best be centralized for economy.

A possible model might be a joint initiative by IRRI, the University of the Philippines at Los Baños, the Philippine Ministry of Health, and a public health organization in Southeast Asia or the Western Pacific. An advisory panel, working

on experience gained by the group, could assist in replicating the approach to meet demands in other regions, assuming that funding could be assured.

TARGET GROUPS

Specific target groups should be identified early in the planning stage of extension training. The first priority and the immediate area of concern of this Workshop is the training of existing professionals who themselves will train and advise others. Agronomists, engineers, and irrigation specialists, particularly those responsible for rice production training, should understand:

- the main vector- and rodent-borne diseases associated with rice production, particularly with irrigated rice, and
- the biology and ecology of ricefield-breeding mosquitoes as main vectors in this habitat.

Equally, medical entomologists and vector-control specialists should be familiar with the principles and practices of rice culture to ensure they understand the objectives and problems of rice production.

Agricultural extension workers, especially those working with irrigation and rice growing, are a prime target group for training. And the farmer must be trained to use whatever methods are finally developed so that he can grow rice free of major vectors without sacrificing yield and quality. Persons living in disease-endemic areas, should learn to use economical personal protection and make use of appropriate health facilities.

There are special groups who must be familiarized with the problems of vector-borne disease and rice production even if only in brief, intensive training sessions. Among these are policy makers, administrators, community leaders, teachers and, where appropriate, religious and social leaders.

INSTITUTIONS

Existing institutions should direct training activities, whether for agronomists and rice specialists or for entomologists. As a first step, such institutions, particularly those able to train the trainers, should be identified and established as collaborating agencies. The UN system and associated agencies offer a ready starting point because they embrace all of these subject areas in relation to the development of riceland ecologies.

Potential funding sources for training activities include the World Bank and Regional Development Banks (ADB, AfDB, WADB, IADB), the UN Development Programme, bilateral agencies, and a number of foundations. The operational and support agencies should include FAO, WHO, and UNEP, together with their PEEM collaborating centers, and various CGIAR organizations—especially IRRI and WARDA with possible participation from CIAT and IITA. IIMI and regional schools of tropical agriculture could participate. Some funding agencies may extend their role to the implementation and operation of training activities, among them the World Bank, which is already engaged in such work.

Training agencies need not necessarily develop their own staffs. They likely will recruit personnel from existing institutions. Training personnel may be borrowed from schools of tropical medicine, schools of public health, and universities throughout the world. National institutions in rice-growing countries would be particularly rich sources of personnel familiar with riceland ecology.

Professional engineering and agronomical organizations, with probable support from ICID, are particularly well suited for training collaboration.

Abstracts

The impact of rice production on vector-borne disease problems in developing countries

N.G. Gratz

Expanding human populations in the tropical developing countries require a continuing expansion of food production. For most of Southeast Asia and the Western Pacific and for increasing areas of Africa and Latin America, this implies great increases in irrigation for rice production. In many countries this at times has resulted in substantial increases in vector populations, particularly mosquitoes and to some degree snails. In most of the tropical disease-endemic countries that has meant an increase in vector-borne disease incidence and prevalence. This has been particularly marked in relation to Japanese encephalitis, which is transmitted almost entirely by ricefield-breeding mosquitoes, and with malaria. In some geographical areas there has also been an increase in schistosomiasis prevalence, particularly from transmission in rice irrigation and drainage canals. Although these increases in disease transmission have not been uniform, it should be remembered that in some areas intended for increased rice production, especially in Africa and Latin America, malaria and a number of arboviruses, which can be readily transmitted by mosquito species breeding in ricefields, are already endemic. *Anopheles gambiae*, the main vector of malaria in Africa, is often found in increased densities in ricefields. Ricefield development for the most part will take place in areas with an already heavy burden of vector-borne diseases. Health and agronomic professions must work closely to avert additional transmission of vector-borne diseases by preventing further vector production in ricefields through economical water or environmental management that will not reduce rice yields.

Tropical rice agroecosystems: characteristics, distribution, and future trends

D.P. Garrity

The tropical rice-growing agroecosystems are diverse at the micro and macro levels. The major classes and subclasses of ricelands are differentiated by water depth and dependability, with wide variation recognized between rainfed agroecosystems.

Hydrological factors, particularly the annual length of flooding, heavily impinge upon the ecology of vector-borne diseases. The relative distribution of ricelands in each of the major hydrological classes also varies between tropical regions as does the prospect for riceland expansion. The geographical zones of disease prevalence raise many questions in relation to the distribution of rice agroecosystems. In Africa and Latin America there is enormous potential to develop wetlands for rainfed and irrigated rice production. Development of these resources is inevitable to meet the exploding demand for rice, but it will require careful attention to disease management at the outset. In Asia, which is largely self sufficient in rice, new irrigation development is slowing, but more attention to the health aspects of sustained rice production systems can be expected. Rice and medical scientists face a major challenge to develop more comprehensive databases on the ecology of vector-environment-management interactions specific to each rice agroecosystem to ensure effective integrated vector-control methods.

The epidemiology of vector-borne disease associated with ricefields

D.J. Bradley

The basic concepts of epidemiology are introduced in the context of ricefield associated diseases. A remarkably high proportion of tropical, especially parasitic, infections are associated with shallow water bodies. Among transient surface waters, ricefields are the world's predominant habitat. Zoonotic arboviruses are transmitted by ricefield-breeding culicine mosquitoes; man is usually a dead-end host and pigs play a major role as amplifying hosts. Malaria is transmitted by anopheline mosquitoes at a wide range of transmission levels as measured by the basic case reproduction rate. In areas of unstable malaria and relatively low transmission, ricefields may provide the only vectors or may increase transmission greatly. Where high levels of transmission of stable malaria already exist, the addition of ricefields and increased anopheline breeding is likely only to prolong the transmission season. Schistosomes, especially *S. japonicum* have strong ricefield associations, but the other species are mainly related to irrigation canals and drains. Many other trematodes have a Southeast Asian distribution, which may be in part due to the long tradition of rice farming in the region. Among these diseases, only malaria looms large in clinical data, but this is because mild, chronic self-limited diseases are over-represented in such data. Great diversity of ricefields as habitats is found, depending upon the proximity of settlements to the fields, the proportion of the land under rice cultivation, and the type of ricefield management as well as the physical environment. This diversity needs to be recognized in the epidemiological aspects of planning vector management.

Planning, design, and operation of rice irrigation schemes: their impact on mosquito-borne disease hazards

K.G.A. Goonasekere and F.P. Amerasinghe

Irrigation schemes in general provide conditions leading to increased mosquito breeding. Rice irrigation schemes in particular are associated with high incidence of human malaria and arboviral diseases. The planning, design, and operational phases of these systems, with particular reference to the ricefield, are reviewed and the ways in which they contribute to mosquito-borne disease problems are considered. Environmental considerations generally rank well below agro-economic priorities in the planning of irrigation schemes. Thus the design often does not incorporate features that reduce opportunities for vector breeding. That and defects in construction and subsequent deficiencies in operation and maintenance, create vector breeding habitats during water delivery and drainage. The ricefield itself provides opportunities for vector production during various phases of the rice-growing cycle, depending on vector species and cultural practices. The impact on vector breeding of asynchronous cultivation, double cropping, natural manures and agrochemicals, and water management are assessed. While proper planning and design can minimize the risks of vector-borne diseases, many developing countries are faced with the problem of controlling such diseases in poorly-designed schemes already in place. The only flexibility left is in operation and management. Attention needs to be focused on operation and management to reduce mosquito-borne diseases in the humans that inhabit these schemes.

Planning, design, and operation of rice irrigation schemes: their impact on schistosomiasis

G. Webbe

In recent years a marked increase in the prevalence and intensity of schistosomiasis in endemic areas has been associated with many man-made water bodies and irrigation projects. Conversion of land to rice-growing may change the general landscape and hydrological pattern of the area, but it does not necessarily lead to schistosomiasis problems. Relatively effective and economical preventive measures may not be possible in water-resource development projects. Simple, rapid, reliable diagnostic techniques to screen residents, migrants, and workers in such developments are available. Those infected may now be treated with relatively cheap and

safe oral drugs. To minimize the risk of introducing schistosomiasis into new development project areas, control can be effectively linked to systematic surveillance to prevent the introduction of snails, which transmit schistosomiasis, or to prevent the onset of transmission by existing snail populations. The prevention of unnecessary human-contact with cercaria infested waters is an important component of integrated schistosomiasis control. Rice irrigation scheme planning should always provide for adequate water supplies and sanitation and siting houses away from canals. Surface waters should be protected by covers, pipes, or fencing and facilities provided for bathing, laundering, and water recreation. Storage facilities should have a minimum supply capacity of 48 h duration. Human behavioral patterns, health education needs, and community participation control must be considered. Problems associated with population movements and resettlements caused by water resource developments are also important. Operational research is required for the engineering and design of water impoundments and irrigation systems to limit snail infestation and for habitat and environmental changes to control snails. Selection of crops, crop rotation, and farming practices may play an important part in schistosomiasis control.

The impact of rice cultural practices of mosquito vector propagation

L.S. Self and S.K. De Datta

Ricefields are flooded to achieve better growth and yield. Flooding also reduces soil toxicity, restores needed oxygen, and helps to control weeds. Water use and moisture stress effects vary at the different stages of growth. The water requirement is low at the seedling stage, but water should be provided immediately after transplanting. Although a large amount of water is consumed in the major part of the reproductive stage, there are times when the fields can be dried to control mosquito larvae. Near maturity, no standing water is required. This paper gives examples of the duration and timing of intermittent irrigation to reduce mosquito vector breeding in Shandong Province, China, and in Japan. Fields can be dried for 2 or 3 d at frequent intervals beginning 2 wk after transplanting. Other control measures, including community participation, are also important to control malaria in the Shandong area. Control measures include moving farm animals outside villages, improving housing structures, screening doors and windows, using untreated mosquito nets and also mosquito nets impregnated with pyrethroid insecticides, and personal repellents. Water management practices to control mosquito larvae must be economical and acceptable to farmers.

Malaria vectors associated with rice culture in Southeast Asia and the Western Pacific

LT. Cowper

Malaria vectors associated with rice culture in Southeast Asia and the Western Pacific vary by country. From available data, the ricefield breeding malaria vectors are *Anopheles culicifacies*, *A. jeyporiensis*, and *A. sinensis*, and they are prominent in many Asian malaria transmission situations. Basic biological information on each of the three species is presented. The identification of other ricefield breeding anophelines is presented but does not encompass all reported work. Basic control methods include biological, physical, and chemical. The importance of studies on suspected or proven vectors and proposed control methods to achieve economical, technically sound, dynamic, and sustainable control in individual situations is stressed.

Vector-borne disease problems associated with rice cultivation and their control in Southeast Asia

Y.H. Bang

Among the vector-borne diseases associated with rice cultivation in Southeast Asia, malaria and Japanese encephalitis are of prime public health concern. With the continued expansion of water development schemes for rice cultivation, a completely new aquatic environment is created, providing more larval habitats and favorable conditions for prolonged longevity of mosquito vectors. More species of disease vectors occur in seepage-fed ricefields in hilly areas than in irrigated plains. Due to the paucity of authentic field data, it is impossible to accurately determine the relative importance of ricefields as larval habitats of disease vectors. In view of technical and operational limitations to chemical control of larvae in ricelands, some examples of successful bio-environmental measures practiced before the DDT era are discussed and recommended.

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Water management in rice production and its relation to mosquito production in Japan

M. Mogi

Despite introducing regular drainage into the rice cultivation pattern, rice still needs considerable irrigation for high yields. This limits the possibilities for manipulating water to control mosquitoes. Carefully designed drainage or flushing could reduce mosquito populations under appropriate combinations of climate, soil, and human behavior. Irrigation and drainage especially designed for mosquito control may be required to increase effectiveness. Combined with the shift of transplanting time, mosquito control will be easier to achieve in temperate zones where low temperature limits mosquito breeding. Control will be more difficult in the tropics and subtropics. Required levels of mosquito control should be considered in relation to the overall integrated disease control program. Although not very effective by themselves, antimosquito measures could still contribute to overall disease control, provided they operated with other control measures and the environment is rendered unfavorable for disease transmission.

Environmental management for the control of ricefield-breeding mosquitoes in China

Lu Bao-lin

Two mosquito species, *Anopheles sinensis* (vector of malaria) and *Culex tritaeniorhynchus* (vector of Japanese encephalitis) are notorious ricefield breeders in China. Environmental management is one of the most important components of the vector control strategy. For these two species population densities follow rice cropping patterns and peaks at certain stages of rice production. Therefore environmental management approaches for their control focus on agricultural practices and water management in ricefields. Manipulation of seedling beds has had reduced mosquito propagation early in the season. However, a more effective vector-control measure has been intermittent irrigation and several regimes have been tested. The most successful and economical of these, the wet-irrigation method, is described in detail. It is extensively applied in Henan Province. In addition, it is attractive for the farmer because it gives higher yields. Currently under investigation is the effect of *Azolla* on the ecology of mosquito vectors breeding in ricefields. Because of its N_2 -fixing ability, *Azolla* is widely used as an organic fertilizer. Preliminary laboratory experiments indicate that *Azolla*, when it covers the entire water surface of ricefields, interferes with the oviposition and aquatic stages of mosquito vectors.

Malaria

J.A. Najera

Various approaches to malaria control in riceland ecosystems and the factors that determine their success or failure are reviewed. The malaria epidemiological patterns of rice-growing areas varies greatly throughout the world. Rice cultivation has been associated with increased malaria transmission in many areas, while in other areas rice cultivation favors nonvector anophelines and is associated with reduced malaria transmission. The interplay of factors related to mosquito genetics, social, and ecological changes affecting man-vector contact, and specific control interventions is analyzed. The current WHO strategy for malaria control based in the primary health care approach is presented. This strategy aims at providing the whole population with appropriate diagnosis and treatment of disease and health education to promote personal and community protection against transmission. This strategy should be complemented by referral systems and the development of epidemiological services, which should organize transmission control interventions in problem areas. The identification of problem areas and the planning and execution of appropriate interventions should follow a research and development approach. The approach should maximize 1) the application of existing knowledge, 2) the opportunities for learning by experience, and 3) the documentation and dissemination of acquired knowledge.

Schistosomiasis in the context of rice production systems in developing countries and strategies for its control

N.R. Bergquist, Chen Ming-gang, and K.E. Mott

The impact of disease and of water irrigation schemes are discussed in general terms including specific references to the epidemiology of schistosomiasis. Brief case reports of schistosomiasis prevalence and control strategies with special regard to rice production in different parts of the world are presented. Case reports are sorted according to WHO regional classifications: Eastern Mediterranean, Africa, Southeast Asia, and the Western Pacific. Human schistosomiasis is described and discussed with emphasis on the important difference between the infection and the disease. Counter measures, taking into account different strategies such as chemotherapy, snail control including molluscicides, biological control, and environmental management as well as sanitation and health education are discussed. Indirect techniques for diagnosis such as chemical reagent strips and detection of specific antibodies are compared to direct means such as classical egg counting and novel techniques that have been devised for detection of circulating antigens. Different strategies such as eradication, transmission control, and morbidity control are discussed with special reference to rice production and other irrigation schemes.

Finally, the possibilities for immunological intervention are reviewed; the characteristics of cloned or otherwise produced promising candidate antigens that are available, are described.

Japanese encephalitis

Y. Wada

Measures to protect humans and pigs and to control mosquitoes to prevent transmission of Japanese encephalitis are discussed. Generally, the first measure to consider is vaccinating humans, because vaccination is well established. The vaccination of pigs, which are the most important amplifying animal of Japanese encephalitis (JE) virus, is of little practical value. Separating pigs from ricefields is the surest way to reduce pig-mosquito contact. Most measures to control vector mosquitoes are of no operational value, at least in the present situation, and need further study. Developing new rice varieties with high yield and reduced water and fertilizer requirements seems a promising method to reduce mosquito density. Another approach is to reduce the number of mosquitoes engorged with pig blood, which may include mosquitoes just infected with JE virus. Modification of pigsty structures, treatment of pigsty walls with residual insecticides, and light traps could be successful. Further studies of these kinds of measures are recommended.

Arboviruses other than Japanese encephalitis

C. Leake

More than 40 viruses have been isolated in studies on riceland agroecosystems but only a few are considered public health problems. Important alphaviruses are O'nyong-nyong from Africa and the equine encephalitis viruses from the Americas. Principal flaviviruses are the West Nile virus distributed from the Mediterranean to South Asia, St. Louis encephalitis from the Americas, and Murray Valley encephalitis from the Indo-Australian archipelago. Several bunyaviruses of increasing significance in the United States are anticipated to be much more widely distributed. These viruses are probably maintained in zoonotic cycles of continuous or possibly transovarial transmission. Principal culicine mosquito vectors are primarily zoophilic with human transmission correlating with peaks in vector density associated with temperature, water availability, and agricultural practice. Clinical care is only supportive; there are no commercially available vaccines. Consideration of the bionomics of these vectors in relation to available integrated control strategies suggest that some transmission reduction might be achieved. Permanent reduction in vector populations would be too costly for developing countries and substantial temporary reduction may be warranted only under epidemic conditions.

Ecology of rodents associated with ricefields and their implications for public health

A.A. Arata

Rodents associated with rice cultivation and related human diseases are described. Rodents associated with rice vary taxonomically in Asia, Africa, and the Americas as do some of the diseases they transmit or harbor. Rice cultivation provides a specialized landscape with ecological elements favorable to rodents and disease transmission. There is, however, a paucity of information on the role of rodents as disease reservoirs in the tropic generally and specifically in areas of rice cultivation. Several areas where additional information is required are suggested. These include details on population densities and seasonality, dynamics of host-pathogen-vector association, and differential susceptibility of rodents to human pathogens.

Integrated mosquito vector control in large-scale rice production systems

D.A. Dame, R.K. Washino, and D.A. Focks

Ricelands in the United States produce floodwater *Aedes* and *Psorophora* spp., whose soilbound eggs hatch shortly after flooding to produce distinct hoods of mosquitoes, and standing-water *Anopheles*, *Culex*, and *Culiseta* spp., which oviposit on the water surface from which mosquitoes continuously emerge. Community-sponsored mosquito control programs commonly include aerial application of *Bacillus thuringiensis* (H-14) or methoprene, combined occasionally with the introduction of mosquito fish against larvae, and aerial and ground ultralow volume applications of fenthion, malathion, naled, or resmethrin against adults. Economical surveillance methods are utilized to support decisions on placement and timing of control applications. New biological control agents that might be effective in riceland situations include fungi, bacteria, and microsporidia; some of these agents could be available within 3 to 5 yr. The number of new candidate insecticides has diminished markedly in recent years, a trend that is expected to continue. To improve the capability for control, more ecological and biological information on mosquito vectors of disease is required. Models for predicting riceland mosquito populations based on annual availability of irrigation water and rainfall, are discussed. Computer simulation models are being devised and utilized because they greatly assist in the selection and timing of control-strategy components.

Integrated mosquito control in small-scale rice production systems

C.H. Schaefer and M.V. Meisch

Integrated control is the utilization of all available control methods in an optimal combination. This can allow for a long-term solution to minimizing losses due to rice pests while limiting the incidence of vector-borne diseases. Also, minimum dependency on chemical control reduces selection pressure and delays the onset of insecticide-resistance. This approach is highly sophisticated, requiring detailed knowledge of all aspects of the crop, associated pests, and the parasite and predator complex. A high degree of interdisciplinary cooperation is essential for planning and executing management strategies. While this appears desirable, it is difficult to achieve and probably will require a single management structure responsible for both rice production and pest and vector control. To implement integrated control on ricefields, the population levels of each key rice pest, vector, and predator species must be monitored. This requires adequate personnel well-trained in aquatic biology. Selective chemical control agents, which do not disrupt the agroecosystem, must be developed for use when biological and environmental control fail.

Control of *Schistosoma japonicum* snail intermediate host in riceland agroecosystems

E. Garcia

The snail host of the geographic strains of *Schistosoma japonicum* endemic in China, Philippines, Japan, and Sulawesi in Indonesia are subspecies of *Oncomelania hupensis*, an amphibian, operculated snail that is strictly aquatic during its first 2 wk of life. Based on the bionomics of *Oncomelania*, environmental control methods that alter the snail habitat have effectively controlled or even eradicated this snail in Japan, in extensive riceland areas in China (excluding Taiwan Province), and in limited areas in the Philippines. These methods include removing water by drainage and proper irrigation water management, removing shade or shelter by clearing vegetation from stream banks or irrigation channels, preventing breeding by lining stream banks and irrigation channels with concrete or making the sides more nearly perpendicular, and accelerating water flow by proper gradient and removing debris. When properly maintained, these alterations lead to snail eradication. Intensive riceland cultivation, with proper seedling spacing, weeding, and water management, has led to snail control in ricefields. That, coupled with snail control in irrigation channels by environmental alterations, controls *Oncomelania* snails in riceland ecosystems.

Control of *Schistosoma mansoni* and *S. haematobium* snail intermediate hosts in ricefields

A.A. El Gaddal

Good water supply and sanitation combined with health education can help to prevent human-pathogen contact in irrigation and drainage canals. Water contact in irrigated ricefields, however, cannot be avoided so easily. Special measures are needed to prevent the invasion of the ricefields by the snail intermediate hosts of the schistosomiasis. Four accepted methods of snail control are discussed. Biological control using snail species that compete with or prey upon intermediate host species is promising. The snail *Marisa cornuarietis*, however, is not a feasible biocontrol agent in ricefields because it feeds on rice seedlings. Interest in natural molluscicides extracted from plants has waned and of the chemical molluscicides only niclosamide is still widely used. Environmental manipulation relies heavily on weed control in canals; aquatic weeds provide habitat and food for snails. Engineering methods, such as the use of meshed siphons, are also important. Finally, the importance of accompanying any control activity aimed at the snail intermediate host with chemotherapy is pointed out. Highly effective and relatively inexpensive drugs are now available, but are useful only when water supply, sanitation, and environment are managed to prevent reinfection. Examples are given from Kenya and Tanzania, where these four measures have been successful to some extent.

A malaria epidemic caused by *Anopheles ludlowi* in East Java in 1933

W.B. Snellen

The outbreak of malaria in a village on the Northern coast of Java, Indonesia, in 1933 was attributed to the formation of brackish pools in saline ricefields, which had not been planted because of abnormally low rainfall. In contrast to the normal practice of identifying breeding sites through larvae finds, meteorological and soil data are used to indicate where and when a combination of environmental factors favorable for vector breeding occurs. A theoretical vector density curve derived from the ponding curve in the saline ricefields appears to correspond with the mortality curve 35 d later. This was considered evidence that breeding of *Anopheles ludlowi* in the saline ricefields caused the epidemic.

Proposed courses and syllabuses for inclusion in engineering curricula

R. Bahar

Planning, design, construction, and operation of water resource development projects usually cover only engineering, technical, and financial aspects. Rarely is there a thorough understanding of their environmental and health implications. Most environmental management measures that can be incorporated into these projects to safeguard health are consistent with good engineering practices. Therefore there is a need to raise the awareness of engineers, in particular, concerning these implications and train them to adequately deal with possible health risks. Courses at different technical levels are proposed, from the technician's level with a focus on information transfer to farmers to research-oriented postgraduate courses. The objectives and target groups for each level are discussed. Professional development courses for practicing engineers are also recommended. The scope, learning objectives, curriculum content, and evaluation of four courses ranging from 5 h to 6 wk duration are presented. All feature five identical topics, but relative weight and teaching methods vary. These courses are not intended to make health professionals of engineers, but to equip them to better predict and subsequently prevent adverse health effects of engineering activities.

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Program

9 March (Monday)

0830 Registration

INAUGURAL SESSION

0900 Welcome address *M.S. Swaminathan*

0915 Opening remarks on behalf of PEEM *R. Slooff*

0930 Introductory comments on behalf of
USDA/RMMP *J.K. Olson*

0945 Coffee break and group photograph

1015 Slide show: "The Rices of IRRI"

1045 Visit to the IRRI research and
training facilities

1200 Lunch

GENERAL SESSION

Chairman: *R. Slooff*

1330 Keynote address: The impact of rice
production on vector-borne disease
problems in developing countries *N.G. Gratz*

1350 Introductory paper 1: Tropical rice
agroecosystems: characteristics,
distribution, and future trends *D.P. Garrity*

1410 Introductory paper 2: The epidemiology of
ricefield associated vector-
borne diseases *D.J. Bradley*

1430 Discussion

1500 Coffee

TECHNICAL SESSION I: Trends in engineering, agronomic, and water management aspects of rice production systems and their impact on disease vectors

Chairman: *T.H. Mather*

1530 Planning, design, and operation of
rice irrigation schemes and their
impact on mosquito-borne disease
hazards *F.P. Amerasinghe*

1550 Discussion

1605 Planning, design and operation of
rice irrigation schemes and their
impact on schistosomiasis *G. Webbe*

1625 Discussion

1830 Reception and dinner at IRRI Guesthouse

10 March (Tuesday)

TECHNICAL SESSION I: (contd.)

0800 Cultural practices of rice production *S.K. De Datta*

0830 The impact of rice cultural practices
on mosquito vector propagation *L.S. Self*

0900 Discussion

0930 Coffee break

0955 Malaria vectors associated with rice
culture in Southeast Asia and the
Western Pacific *L. Cowper*

1010 Discussion

1025 Case studies of vector-borne disease
problems associated with rice
cultivation

(a) Southeast Asia *Y.H. Bang*

(b) Japan *M. Mogi*

(c) People's Republic of China *Lu Bao-lin*

1125 General discussion

1200 Lunch

TECHNICAL SESSION II: Strategies for vector-borne disease control in rice production systems

Chairman: *J.A. Najera*

1300 Malaria *J.A. Najera*

1350 Discussion

1405 Schistosomiasis *N.R. Bergquist*

1425 Discussion

1440 Japanese encephalitis *Y. Wada*

1500 Discussion

1515 Coffee break

1535 Arboviruses other than Japanese encephalitis *C. Leake*

1555 Discussion

1610 Ecology of rodents associated with
ricefields and their implications
for public health *A.A. Arata*

1630 General discussion

- 1930 Special seminar: The management
of Laguna Lake and its watershed
(Chandler Hall auditorium) *M.D. Lopez*

11 March (Wednesday)

**TECHNICAL SESSION III: Integrated
vector control strategies in rice production
systems in developing countries**

Chairman: *J.K. Olson*

- 0800 Integrated mosquito vector control in
large-scale rice production systems *D.A. Dame*
- 0830 Integrated mosquito vector control
in small-scale rice production
systems *C. Schaefer*
- 0900 Discussion
- 0940 Coffee break
- 1010 Control of the *Schistosoma*
japonica snail intermediate host
in riceland agroecosystems *E. Garcia*
- 1030 Discussion
- 1050 A malaria epidemic caused by
Anopheles ludlowi in East
Java in 1933 *W.B. Snellen*
- 1110 Discussion
- 1125 Proposed courses and syllabuses
for inclusion in engineering
curricula *R. Bahar*
- 1145 Discussion
- 1200 Lunch

1330 Poster session on integrated vector control methods, monitoring, and evaluation

1430 Division of participants into three working groups

 Group 1: Research as a basis for control

 Group 2: Intervention research toward the development of control methods

 Group 3: Training needs: subject matter, target groups, and institutions

1500 Coffee break

1530 Working groups convene separately to formulate work plans

March 12 (Thursday)

0800 Working groups convene to discuss and prepare their reports

1600 IRRI Thursday seminar: Environmental management for disease vector control *R. Bos*

12 March (Friday)

 PLENARY SESSION: Working group reports
 Chairman: *G. Webbe*

0900 Review of group reports

0930 Group 1 report *B.H. Kay*

0945 Discussion

- 1030 Coffee Break
- 1050 Group 2 report *J.K. Olson*
- 1105 Discussion
- 1150 Group 3 report *N.G. Gratz*
- 1205 Discussion
- 1245 Lunch
- 1400 Working groups reconvene to formulate
final recommendations

14 March (Saturday)

CONCLUDING SESSION: Presentation of recommendations

Chairman: *M.S. Swaminathan*

- 0800 Groups 1 and 2: Research needs *J.K. Olson*
- Discussion
- Group 3: Training needs *N.G. Gratz*
- Discussion
- 0915 Concluding comments *R. Slooff*
J.K. Olson
- 0930 Chairman's closing remarks

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